(19)日本国特許庁（ＪＰ）　(12)**公開特許公報**（Ａ）　(11)特許出願公開番号

特開平9－33202

(43)公開日　平成９年(1997)２月７日

(51)Int.Cl.[6]	識別記号	庁内整理番号	ＦＩ		技術表示箇所
Ｇ０１Ｂ　7/00			Ｇ０１Ｂ　7/00	Ｄ	
Ｇ０１Ｄ　5/20			Ｇ０１Ｄ　5/20	Ｐ	

審査請求　未請求　請求項の数６　ＦＤ　（全 10 頁）

(21)出願番号　特願平7－206834

(22)出願日　平成７年(1995)７月21日

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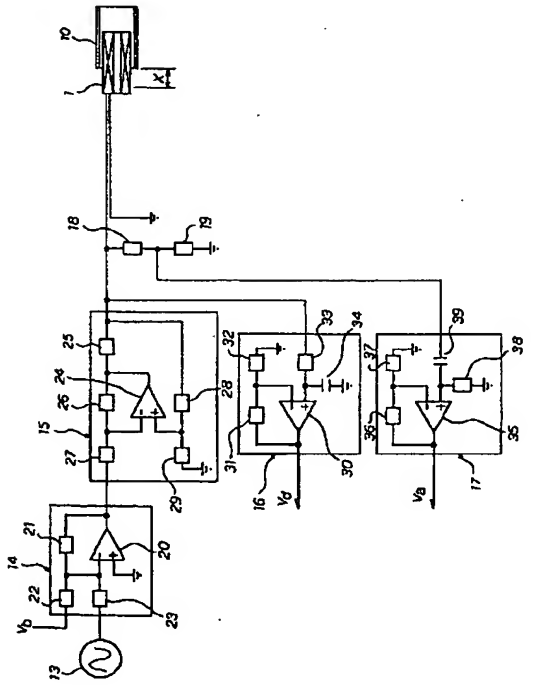
(54)【発明の名称】　変位検出装置

(57)【要約】

【課題】　変位を検出するコイルを１個とし、装置の小型化を図るとともに、周囲温度によって測定結果が影響を受けることの少ない変位検出装置の提供。

【解決手段】　一定の長さに巻回したコイル１と、コイル１とほぼ同等或いはそれ以上の長さを有する非磁性で比較的電気良導体からなる外筒１０をコイル１の軸線方向に移動可能に配設し、コイル１に直流電流で偏倚された交流電流を供給し外筒１０のコイル１に対する相対変位に比例的に変化するコイル１の端子間の直流偏倚分を除く交流電圧信号、又はこの交流電圧を直流電圧若しくは直流電流に交換した信号を出力とする。



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【特許請求の範囲】

【請求項１】　一定の長さに巻回したコイルと、前記コイルとほぼ同等或いはそれ以上の長さを有する非磁性で比較的電気良導体からなる外筒を前記コイルの軸線方向に移動可能に配設し、前記コイルに直流電流で偏倚された交流電流を供給し前記外筒の前記コイルに対する相対変位に比例的に変化する前記コイルの端子間の直流偏倚分を除く交流電圧信号、又は前記交流電圧を直流電圧若しくは直流電流に交換した信号を出力とすることを特徴とする、変位検出装置。

【請求項２】　請求項１に記載の変位検出装置において、前記コイルの端子間に２組の抵抗回路を直列に接続し、前記抵抗回路の少なくとも一方の抵抗値を前記コイル端子間に発生する直流電圧に比例的に変化させ、前記抵抗回路の接合点に得られる直流偏倚分を除いた電圧変化をもとに出力信号を得ることを特徴とする、変位検出装置。

【請求項３】　請求項１に記載の変位検出装置において、前記コイルの端子間にポテンショメータを接続し、前記ポテンショメータの分圧比を前記コイル端子間に発生する直流電圧に応じて変化させ、前記ポテンショメータのワイパー電圧の直流偏倚分を除いた電圧変化をもとに出力信号を得ることを特徴とする、変位検出装置。

【請求項４】　請求項１に記載の変位検出装置において、前記コイルに供給される直流偏倚分を除いた交流電流の振幅を前記コイル端子間に発生する直流電圧に応じて変化させ、前記コイル端子間の直流偏倚分を除いた電圧変化をもとに出力信号を得ることを特徴とする、変位検出装置。

【請求項５】請求項１に記載の変位検出装置において、前記コイルに供給される直流偏倚分を除いた交流電流の励振源としてクワドラチュア発振器を用い、該発振器の出力の振幅を制限する抵抗及びダイオードからなる回路に供給する電圧を前記コイル端子間に発生する直流電圧に応じて変化させ、前記コイル端子間の直流偏倚分を除いた電圧変化をもとに出力信号を得ることを特徴とする、変位検出装置。

【請求項６】請求項１に記載の変位検出装置において、前記コイルに供給される直流偏倚分を除いた交流電流の励振源としてクワドラチュア発振器を用い、該発振器の出力の振幅を制限する抵抗及びダイオードからなる回路に供給する電圧を、前記クワドラチュア発振器の交流出力の振幅或いは実効値に比例する直流電圧と基準電圧との差に基づき変化させるとともに、前記コイル端子間に発生する直流電圧によっても変化させ、前記コイル端子間の直流偏倚分を除いた電圧変化をもとに出力信号を得ることを特徴とする、変位検出装置。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、産業機械装置の機械的

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変位、或いは液体のレベル変化を浮子等による機械的変位に変換して、その変化を電気信号として出力する変位検出装置に関する。

【０００２】

【従来の技術及びその課題】変位を検出する装置として従来から種々の方式が提案されている。最も古典的なものとしては、差動トランス或いはポテンショメータなどを挙げることが出来る。差動トランスは基本的に無接触で変位を検出できるが、その原理構造上、有効な変位検出測定範囲に対して検出装置の変位検出方向長さが大きくなる欠点があるとともに、検出装置の可動部（差動トランスのコア）が機械的振動、衝撃によって破損し易い欠点がある。ポテンショメータは安価であることから多くの機械装置に用いられているが、原理的に接触式変位検出装置であり、寿命に限界があるといった問題がある。

【０００３】無接触である特徴を維持しながら上記従来方式（特に差動トランス）を改良した例として、特開昭６３－２７３００１号、特開昭６３－２７３００２号、特開平２－１１６７１２号、特開平２－２０１１１４号及び特開平３－４６５１２号などを挙げることができる。これらの例は、いずれもコイルの中心部に設けられるコアは固定しておき、このコイルの外周部に金属外筒をコイルの軸線方向に移動可能なように配設し、金属外筒のコイルに対する相対変位を電気信号に変換するものである。

【０００４】この改良例は、上記公開特許公報に記載されているように、機械的に強い構造を有する変位検出装置を具現できることになる。

【０００５】しかしながら、変位検出装置においては、その機械的構造の強さだけでなく、その性能、特に周囲の温度変化に対して出力信号の変化が少ないものが要求される。

【０００６】特開昭６３－２７３００１号では、温度特性を良くするためにコイルＡとＢの２個を軸方向に設けている。この方式であると、コイルが２個になるため装置の軸方向長さが大きくなる。この欠点を改善するため、特開昭６３－２７３００２号では２個のコイルを並設する方式を提案している。

【０００７】特開平２－１１６７１２号では２個のコイルの一方を別な場所に設置し、変位検出装置の小型化を図っている。特開平２－２０１１１４号及び特開平３－４６５１２号も同様の考えで小型化を提案したものである。

【０００８】いずれにしても、２個のコイルを差動型に接続して変位検出装置の温度特性を良くしようとするものである。しかしながら、この方式でも、実際上は３００～９００ppm/℃と非常に大きな温度特性しか得られていない。この理由は、コイルを２個用いて差動型にしても、当然のことながら、変位に応じて２個のコイルが異

なるインダクタンスを有するため完全な温度補償ができないためである。

【０００９】

【発明の目的】そこで、本発明は、変位を検出するためのコイルを１個として装置の小型化を図るとともに、コイルを直流成分でバイアスされた交流電流で駆動し、この直流成分によって生ずる直流電圧変化が周囲温度によって比例的に変化することを応用して温度補償特性の優れた変位検出装置を提案するものである。

【００１０】

【課題を解決するための手段】本発明は、一定の長さに巻回したコイルと、前記コイルとほぼ同等或いはそれ以上の長さを有する非磁性で比較的電気良導体からなる外筒を前記コイルの軸線方向に移動可能に配設し、前記コイルに直流電流で偏倚された交流電流を供給し前記外筒の前記コイルに対する相対変位に比例的に変化する前記コイルの端子間の直流偏倚分を除く交流電圧信号、又は前記交流電圧を直流電圧若しくは直流電流に交換した信号を出力とすることを特徴とする変位検出装置によって、前記課題を解決した。

【００１１】なお、本発明の好適な実施態様としては、■コイルの端子間に２組の抵抗回路を直列に接続し、この抵抗回路の少なくとも一方の抵抗値をコイル端子間に発生する直流電圧に比例的に変化させ、この抵抗回路の接合点に得られる直流偏倚分を除いた電圧変化をもとに出力信号を得る変位検出装置、■コイルの端子間にポテンショメータを接続し、このポテンショメータの分圧比をコイル端子間に発生する直流電圧に応じて変化させ、このポテンショメータのワイパー電圧の直流偏倚分を除いた電圧変化をもとに出力信号を得る変位検出装置、■コイルに供給される直流偏倚分を除いた交流電流の振幅をコイル端子間に発生する直流電圧に応じて変化させ、このコイル端子間の直流偏倚分を除いた電圧変化をもとに出力信号を得る変位検出装置、■コイルに供給される直流偏倚分を除いた交流電流の励振源としてクワドラチュア発振器を用い、この発振器の出力の振幅を制限する抵抗及びダイオードからなる回路に供給する電圧をコイル端子間に発生する直流電圧に応じて変化させ、このコイル端子間の直流偏倚分を除いた電圧変化をもとに出力信号を得る変位検出装置、及び■コイルに供給される直流偏倚分を除いた交流電流の励振源としてクワドラチュア発振器を用い、この発振器の出力の振幅を制限する抵抗及びダイオードからなる回路に供給する電圧を、このクワドラチュア発振器の交流出力の振幅或いは実効値に比例する直流電圧と基準電圧との差に基づき変化させるとともに、コイル端子間に発生する直流電圧によっても変化させ、このコイル端子間の直流偏倚分を除いた電圧変化をもとに出力信号を得る変位検出装置がある。

【００１２】

【作用】本発明においては、交流信号によって駆動されるコイルは１個であり、前記コイルに直流電流で偏倚された交流電流を供給し前記外筒の前記コイルに対する相対変位に比例的に変化する前記コイルの端子間の直流偏倚分を除く交流電圧信号、又は前記交流電圧を直流電圧若しくは直流電流に交換した信号として取り出すことができるから、この種変位検出装置の小型化を実現することができるとともに、温度補償特性の向上を図ることが可能になる。

【００１３】

【実施例】図１は本発明の実施例の変位検出装置の一例を示す。図１において、コイル１はボビン２に巻回されている。本例ではコイル１は２層に巻回されているが１層でもよいし、また２層を超える多層巻でもよい。コイル１は変位検出軸方向に１個だけ設けたもので、このコイルの引出し線３と４が図２、図７、図８及び図９に示される電気回路に接続される。金属パイプ５は、非磁性で比較的電気不良導体、例えば、オーステナイト系ステンレスＳＵＳ３０４等の金属パイプからなり、この金属パイプ５の両端は、先端プラグ６とヘッドプラグ７で封止された密閉構造になっている。本例では、符号８と９で示すように、溶接によって封止しているが、Ｏリング等でシール性を持たせた取付方法でもよい。本発明の動作原理からいって、先端プラグ６とヘッドプラグ７も金属パイプ５と同様な材質が望ましい。また、機械的強度を余り要求しないような場合は、５，６及び７をプラスティック或いはセラミックスなどの材質で構成してもよい。

【００１４】外筒１０は、非磁性で比較的電気良導体、例えば、銅、銅合金、アルミニウム或いはアルミニウム合金などから製作される。この外筒１０は、コイル１の軸線方向でコイル１に対して相対変位し、外筒１０がコイル１に対して一種のショートコイルの役をなし、外筒１０の変位に応じてコイル１のインダクタンスが変化するようになっている。コア１１は、ボビン２の中心部に挿入され透磁率の良い材質、例えば、パーマロイなどが望ましいが、コア１１は必須のものではなく、ボビン２の中心部は空洞でもよい。ただし空洞の場合はコイル１のインダクタンスの外筒１０の変位に対する変化率（感度）が小さくなることを覚悟しなければならない。

【００１５】なお、図１の符号１２は、ヘッドプラグ７に設けられたねじ部であり、後述する応用例図１０に示すように機器にねじ込むことができるようにしたものである。

【００１６】次に、図２は、本発明の変位検出器の主たる部分であるコイル１を駆動する電気回路及び信号検出回路を示す。図２の回路は、励振源１３、加算器１４、電圧・電流変換器１５、低域フィルタ１６、高域フィルタ１７、抵抗素子１８及び抵抗素子１９から構成される。コイル１の引出し線３，４の一方は電圧・電流変換器１５の出力に接続され、他の引出し線は図２の回路の

グランドに接続される。

【００１７】励振源１３は、図３の左図に示すようなＯｖを中心に振れる交流信号、望ましくは、正弦波状交流信号を出力する。加算器１４は演算増幅器２０、抵抗２１，２２及び２３から構成され、この加算器１４の出力は図３の右図に示すようなＶｂだけＯｖから偏倚された交流信号となる。この加算器１４の出力は次段の電圧・電流変換器１５に印加され、この印加された電圧に比例した電流がコイル１に流れることになる。すなわち、図３の右図に示すような電流値０から偏倚された交流電流がコイル１に流れることになる。ただし、図３の右図は加算器１４の出力を示す。

【００１８】なお、電圧・電流変換器１５は，演算増幅器２４、抵抗２５，２６，２７，２８及び２９から構成される典型的従来例の一つを示したに過ぎない。コイル１に加算器１４の出力電圧に比例した電流を供給できる回路であればどのようなものでも良い。既に述べたように外筒１０のコイル１に対する相対変位に比例的にコイル１のインダクタンスが変化するので、このコイル１の２つの引出し線３と４の間には外筒１０のコイル１に対する相対変位に比例的に変化する交流電圧信号が得られることになる。コイル１のインダクタンスは外筒１０が図２で右方向に移動（Ｘが大きくなる方向）するに比例して大きくなるので、上記した交流電圧も比例的に大きくなる。

【００１９】コイル１の２つの引出し線３と４の間の電圧は抵抗素子１８及び抵抗素子１９で分圧され、この分圧された電圧が高域フィルタ１７に伝えられる。高域フィルタ１７は演算増幅器３５、抵抗３６，３７，３８及びコンデンサ３９からなる典型的な回路である。抵抗３８とコンデンサ３９の値を適当に選べば，図３の右図に示すような直流偏倚－Ｖｂの除去されたＯｖを中心に振れる交流信号のみを高域フィルタ１７の出力Ｖａとして得ることができる。このＶａは，既に述べた如く、周囲温度が一定であれば、外筒１０のコイル１に対する相対変位に比例する。

【００２０】また、コイル１の２つの引出し線３と４の間の電圧は低域フィルタ１６にも伝えられるようになっており、この低域フィルタ１６は演算増幅器３０、抵抗３１，３２，３３及びコンデンサ３４からなる典型的な回路で、抵抗３３とコンデンサ３４の値を適当に選べば図３の右図に示すような直流偏倚－Ｖｂに相当する直流電圧Ｖｄを得ることができる。

【００２１】さて、上記の直流電圧Ｖｄは、コイル１の直流抵抗値に比例し、この直流抵抗値はコイル１の周囲温度Ｔに比例しコイル１のインダクタンスには無関係である。すなわち、α、βを定数とするとＶｄは次の式で表わすことができる。

Ｖｄ＝α・Ｔ＋β　　…■

後述する実験結果からも明らかなように、コイル１のインダクタンスは外筒１０の変位に応じて変化するのみならず、コイル１の周囲温度の変化によっても変動する。本発明の中心的特徴は，■式で示される関係を応用して温度特性の優れた変位検出装置を提案するところにある。

【００２２】

【実験例】本発明の効果を実証するために、図１で示す変位検出装置を試作した。コイル１の線径は０．２　で、軸方向長さを１５０　、ボビン２の外径、すなわち、コイル１の内径は４　とし２層巻回した。外筒１０の有効移動範囲は、コイル１の軸方向長さ１５０　の両端から１０　以内、すなわち、１３０　とした。

【００２３】図４、図５及び図６は実験結果の一例を示し、図４はＸ＝０　、図５はＸ＝６５　及び図６はＸ＝１３０　の場合を示す。図の中の横軸は周囲温度で、縦軸は高域フィルタ１７の出力Ｖａの電圧を示す。実験では抵抗素子１９を固定抵抗２０ＫΩとし、抵抗素子１８を０Ωから１００Ω毎に変化させた。すなわち、図４～図５において０Ωと記した実験結果は抵抗素子１８と１９による分圧効果のない場合を示す。

【００２４】これらの実験結果から明らかなように、コイル１のインダクタンスの大きさ、言い換えると外筒１０の位置の差異によって、出力信号の周囲温度に対する変化率が大きく異なることが分かる。例えば、抵抗素子１８が０Ωの場合、変位検出装置の有効測定範囲１３０　をフルストローク（ＦＳ）として温度特性を計算すると、

Ｘ＝０　のとき　　４８５ppmFS／℃
Ｘ＝６５　のとき　　１００４ppmFS／℃
Ｘ＝１３０　のとき　１５２４ppmFS／℃

であった。（注：周囲温度２０℃一定の条件下で外筒１０が１３０　変位したときのＶａの変化は３７８３mvACであった。この３７８３mvACに対する１℃当りの変動率を ppmで表わしたものが上記の各数値である。）

【００２５】このように、変位によって温度特性の異なることが、前述した先行技術によるコイル２個を使用した差動方式にしても完全に温度補償しきれない理由である。

【００２６】さて、図４～図５の実験結果から、次に示す線形方程式でデータを近似できることが分かった。

Ｘ＝０　のとき　Ｖａ＝１．８３３・Ｔ＋Ｄ１－（７／１００）・Ｒｘ　…■
Ｘ＝６５　のとき
Ｖａ＝３．８００・Ｔ＋Ｄ２－（１５／１００）・Ｒｘ…■
Ｘ＝１３０　のとき
Ｖａ＝５．８７６７・Ｔ＋Ｄ３－（２３／１００）・Ｒｘ

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但し、Ｖａ：高域フィルタ１７の出力
Ｔ　：周囲温度
Ｒｘ：抵抗素子１８の抵抗値
Ｄ１，Ｄ２及びＤ３：Ｔ＝０、Ｒｘ＝０のときの出力信号Ｖａの値

【００２７】ここで、Ｒｘが周囲温度に対して線形にそ

$$Va=[3.800-(15/100)\cdot\kappa 1]\cdot T+D2-15\kappa 2/100 \quad \cdots■$$

となる。

【００２８】■式において周囲温度Ｔの係数が０であれば、少なくともＸ＝６５　のとき、高域フィルタ１７の出力信号Ｖａは周囲温度に全く影響されないことになる。そこで、この場合のκ１の値を求めると、

３．８００－１５／１００・κ１＝０
κ１＝２５．３３３　　…■

■式で得られたκ１をＸ＝０　及びＸ＝１３０　の場合

Ｘ＝０　のとき　　０．０６／３７８３＝１５．８ppmFS／℃
Ｘ＝１３０　のとき　－０．０６／３７８３＝１５．８ppmFS／℃

となり、変位検出装置の有効移動範囲全域で非常に優れた温度特性を得ることができることが分かった。

【００２９】既に述べたように、■式で低域フィルタ１６の出力Ｖｄは周囲の温度Ｔに比例することを示した。従って、Ｖｄに対し比例的に抵抗素子１８の抵抗値を変化させることができれば、本発明による効果を得ることができることになる。図２では詳細を図示しないが、例えば、抵抗素子１８をＦＥＴトランジスタとし、そのゲート電圧を低域フィルタ１６の出力Ｖｄで制御してやると上記した効果が得られることになる。

【００３０】図７は本発明の実施例のより具体的な一例を示したものである。なお、図２で示した回路の構成部品と同一機能を有するものに対しては同じ番号を付した。

【００３１】図２における抵抗素子１８と抵抗素子１９に代えてディジタル・ポテンショメータ４２（具体的にはアナログ・デバイセズ社製半導体集積回路ＡＤ８４０２等を用いることができる。）を使用した例である。このディジタル・ポテンショメータ４２は、演算回路４１

（２０・１０の３乗）／（２０・１０の３乗＋２５．３３３・Ｔ）　…■

となる。

【００３３】従って、図７の回路においては、ポテンショメータ４３の分圧比、言い換えるとポテンショメータ４３のワイパー４４の位置を■式で示す関係によって決めるとよい。既に述べたように，周囲温度Ｔは■式から容易に求めることができる。

【００３４】図８は本発明の他の実施例を示したものである。図８においても、図２又は図７で示した回路の構成部品と同一機能を有するものに対しては同じ番号を付した。図７ではポテンショメータ４３をコイル１の引出し線の間に設けているが、図８ではポテンショメータ４

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…■

の抵抗値を変化し得るとすると、

Ｒｘ＝κ１Ｔ　＋　κ２　　…■

但し、κ１、κ２は定数

となり、これをＸ＝６５　のときの方程式■に代入すれば、

$$Va=[3.800-(15/100)\cdot\kappa 1]\cdot T+D2-15\kappa 2/100 \quad \cdots■$$

の方程式■と■に代入すると、それぞれのＴの係数は、

Ｘ＝０　のとき　　０．０６
Ｘ＝１３０　のとき　－０．０６

となる。本試作品における外筒１０の有効移動範囲（周囲温度２０℃一定条件下）での出力電圧Ｖａの最大変差は３７８３mvACであったので、これをフルストロークとし温度特性を計算すれば、

Ｘ＝０　のとき　　０．０６／３７８３＝１５．８ppmFS／℃
Ｘ＝１３０　のとき　－０．０６／３７８３＝１５．８ppmFS／℃

のディジタル信号によってポテンショメータ４３のワイパー４４の位置を任意に設定できるものである。すなわち、ポテンショメータ４３のワイパー４４に得られる電圧は、図２における抵抗素子１８と抵抗素子１９によって分圧された電圧と等価である。

【００３２】ここで、低域フィルタ１６の出力信号ＶｄをＡ／Ｄ変換器４０でディジタル信号に変換し、マイクロプロセッサなどで構成される演算回路４１によってディジタル・ポテンショメータ４２を制御すべきディジタル信号を得て、周囲温度に応じポテンショメータ４３のワイパー４４の位置を決めるとよい。この点をもう少し詳しく説明すると次のようになる。すなわち、図２において抵抗素子１９を２０ＫΩの固定抵抗とした場合、■式にみるようにκ１＝２５．３３３が最適であった。このことは、■式より明らかなように、Ｒｘを周囲の温度が1℃変化する毎に２５．３３３Ωづつ減ずればよいことを示している。これを抵抗素子１８と抵抗素子１９の分圧比として表わすと、

３のワイパー４４の信号が加算器１４に印加されるようになっている。また、外筒１０の変位に応じて変化する、コイル１の信号は直接高域フィルタ１７に伝えられ出力信号Ｖａが取出されるようになっている。

【００３５】コイル１の周囲温度の変化は、既に述べたように、低域フィルタ１６の出力信号Ｖｄとして検出され、この出力信号ＶｄはＡ／Ｄ変換器４０によってディジタル信号に変換され、演算回路４１によりディジタルポテンショメータ４２を制御すべきディジタル信号を得て周囲温度に応じポテンショメータ４３のワイパー４４の位置が決められる。すなわち、周囲温度が変化する

と、それに応じて励振源１３の交流信号の振幅が変化し、この振幅の変化した交流信号が加算器１４に加えられて、最終的には、周囲温度の変化に感応しない変位信号Ｖａを得ようとするものである。

【００３６】この点を数式を用いて説明すると次のようになる。図４、図５及び図６のＲｘ＝０Ωのときのグラフからも明らかなように、変位検出装置の出力信号Ｖａの周囲温度Ｔによる変動分△Ｖａは■式で表わされる。

△Ｖａ＝（α１・Ｘ＋β１）・Ｔ　…■

■式のβ１はＸ＝０のときの温度Ｔに対する感度係数で、α１・Ｘはこの感度係数がＸの大きさに応じて大きくなることを示している。α１、β１ともコイル１の仕様によって一義的に決まる係数である。

【００３７】また、周囲温度Ｔは■式でも明らかなように、低域フィルタ１６の出力Ｖｄとして検出でき、その変動分△Ｖｄを(１０)式のように示す。

△Ｖｄ＝α２・Ｔ　…(１０)

さて、変位検出装置の出力信号Ｖｄはコイル１に加えられる交流信号の大きさによっても変化する。励振源１３の出力する交流信号の大きさをＶｄで制御できるように図８の回路は構成されているので、この制御による出力信号Ｖａの変動分△Ｖａは、

△Ｖａ＝（α３・Ｘ＋β３）・△Ｖｄ　…(１１)

となる。(１１)式は、当然のことながら、Ｖｄに対するＶａの変化率がＸの大きさ、すなわち、コイル１のインダクタンスの大きさに依存することを示している。

【００３８】（１０）、（１１）式から次の（１２）式を得る。

△Ｖａ＝（α３・Ｘ＋β３）・α２・Ｔ　…（１２）

（９）式と（１２）式の差をとると、

$$(\alpha_1 \cdot X+\beta_1)\cdot T-(\alpha_3 \cdot X+\beta_3)\cdot \alpha_2 \cdot T$$
$$=[(\alpha_1-\alpha_3\cdot\alpha_2)\cdot X-(\beta_1-\beta_3\cdot\alpha_2)]\cdot T \quad \cdots(13)$$

となる。

【００３９】（１３）式から明らかなように、

$\alpha_1-\alpha_3\cdot\alpha_2=0$　…（１４）

$\beta_1-\beta_3\cdot\alpha_2=0$　…（１５）

が成立すれば、周囲温度Ｔに全く影響されないことになる。

【００４０】具体的な数値を（１４）、（１５）式に適用してみる。既に述べたように、α１、β１はコイル１の仕様によって決まり、試作変位検出装置では（２）、（３）及び（４）式から、

α１＝３０．２６×（１０の－３乗)

β１＝１．８３３

また、α３とβ３は、

α３＝５．４９８×（１０の－３乗)

β３＝０．３３３

であった。α２は任意に選べるので（１４）式から、

α２＝α１／ａ３＝５．５０４

と選べば、先ず（１４）式が満足される。次に、上記のβ１、β３及びα２を（１５）式に代入すれば、

$$\beta_1-\beta_3\cdot\alpha_2=1.833-0.333\times5.504$$
$$\fallingdotseq 0$$

となって（１５）式も満足される。

【００４１】図８の実施例では励振源１３の交流信号の振幅を変化させるためにディジタルポテンショメータ４２を用い、このディジタルポテンショメータ４２を制御するために演算回路４１とＡ／Ｄ変換器４０が必要となって回路構成が若干複雑になる。この点に鑑み、全ての回路をアナログ回路で構成したさらに他の実施例を図９に示す。

【００４２】図９では図８の励振源１３に相当するものとしてクワドラチュア(Quadrature)発振回路４５を用いた。演算増幅器５０、コンデンサ５２及び抵抗５５からなる積分回路と演算増幅器５１、コンデンサ５３及び抵抗５６からなるもう一つの積分回路を抵抗５７及びコンデンサ５３で閉回路になし、自励振動によって、演算増幅器５０の出力に０Ｖを中心に振動する正弦波を得るものである。

【００４３】発振周波数ｆは、コンデンサ５２、５３及び５４を等しくＣとし、抵抗５５、５６を等しくＲとし、抵抗５７を１０％以下程度でＲよりも大きめにすれば安定した発振が得られ、

$f=1/2\pi RC$

となる。

【００４４】引出し線４９上の正弦波の振幅は抵抗５８，５９，６０及び６１とダイオード６２及び６３で制限され抵抗５８及び６１を経て外部から供給される電圧Ｖｅ及び－Ｖｅに比例する。

【００４５】さて、符号４６は、例えば、全波整流器などであって、正弦波の実効値或いは振幅の大きさなどの直流信号を出力するもので加減算器４７に負帰還される。加減算器４７は演算増幅器６４、抵抗６５，６６，６７及び６８からなる位相反転増幅器である。今、コイル１の周囲温度に比例する低減フィルタ１６の出力電圧Ｖｄが０ｖであると仮定する。抵抗６５の値を抵抗６６及び６８よりも比較的に大きくしておくと、抵抗６８を経て外部から印加される一定電圧－Ｖｃの絶対値に全波整流器４６の出力が一致するよう電圧Ｖｅが制御される。符号４８は典型的な位相反転回路であり、演算増幅器６９、同じ抵抗値を有する抵抗７０及び７１から構成され－Ｖｅを出力し抵抗６１を経てクワドラチュア発振回路４５に供給される。すなわち、図９で示す実施例によって、外部から印加される一定電圧－Ｖｃの絶対値に比例した振幅を有する０ｖを中心に振れる正弦波を引出

し線４９に得ることが可能となる。

【００４６】さて、次にコイル１の周囲温度が変化した場合を考える。既に述べたように、この周囲温度は低減フィルタ１６の出力電圧Ｖｄとして（１）式の関係で検出できる。Ｖｄは図９における加減算器４７の抵抗６７を経てこの加減算器に印加されるので、引出し線４９に得られる正弦波の振幅はコイル１の周囲温度の変動に応じて変化することになる。抵抗６７の抵抗値を抵抗６６及び６７の抵抗値に対し適当に選べば、既に述べた（１４）及び（１５）式を満足することができる。

【００４７】なお、外筒１０のコイル１に対する相対変位に比例する出力信号Ｖａは、その実効値を出力としてもよいし、従来技術で容易に得ることのできる整流された直流電圧を出力信号としてもよい。或いは、Ｖａが正弦波の場合は、そのピーク値をホールドし直流電圧に変換したものでもよい。いずれにしても、外筒１０の変位に比例した目的にかなった電気信号を容易に得ることができる。また、電圧信号に限らず、電流信号にしてもよい。

【００４８】

【応用例】図１０は本発明による変位検出装置を油空圧シリンダに組込みシリンダのロッドの変位を検出する例を示したものである。図１で示した構成の変位検出装置７２が油圧シリンダ７３の側底部にねじ込まれ、Ｏリング５０でシールされる。すなわち、加圧流体の加えられるシリンダ等に内蔵しうる例を図１０は示している。

【００４９】変位検出装置の外筒１０はロッド７４の中心部に設けられた穴７８に挿入され、この外筒１０の端部に固着されたフランジ７５をボルト７６でシリンダのピストン部７９に取付けられている。この構造によって、シリンダ７３のポート８０或いは８１を経て加圧された流体がシリンダ７３の内部に供給され、ロッド７４が伸縮し、この伸縮の変位を本発明による変位検出装置７２が検出する。このように、図１における金属パイプ５、先端プラグ６及びヘッドプラグ７で密閉された強固な容器の中にコイル１を収納できる構造であるから、図９のような応用例に用いることが可能となる。

【００５０】当然のことであるが、応用例は図１０に限られず、一般的な産業機械の可動部位に外筒１０を取付けて変位を検出できることは言うまでもない。

【００５１】

【発明の効果】請求項１の構成によれば、変位を検出するためのコイルを１個としたので、小型化されたこの種の変位検出装置を得ることができる。そして、請求項２乃至６の構成では、温度補償特性の優れた変位検出装置を得ることができる。

【図面の簡単な説明】

【図１】　本発明の変位検出装置の実施例の軸方向断面図。

【図２】　図１の変位検出装置の概略とその駆動回路及び信号検出回路の実施例を示した図。

【図３】　左側は励振源のＯｖを中心に振れる交流信号出力、右側はＶｂだけＯｖから偏倚された加算器の交流信号出力の波形をそれぞれ示す。

【図４】　出力電圧が周囲温度によってどのように影響されるかを示した実験結果を示す図表で、変位がゼロの場合である。

【図５】　出力電圧が周囲温度によってどのように影響されるかを示した実験結果を示す図表で、変位が中間の場合である。

【図６】　出力電圧が周囲温度によってどのように影響されるかを示した実験結果を示す図表で、変位が最大の場合である。

【図７】　図１の変位検出装置の概略とその駆動回路及び信号検出回路の別の実施例を示した図。

【図８】　図１の変位検出装置の概略とその駆動回路及び信号検出回路のさらに別の実施例を示した図。

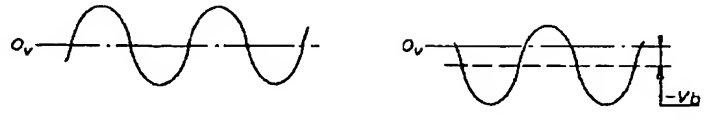
【図９】　図１の変位検出装置の概略とその駆動回路及び信号検出回路のさらに別の実施例を示した図。

【図１０】　本発明の応用例で、油空圧シリンダに組み込まれ、シリンダのロッドの変位を検出する場合の軸方向断面図。

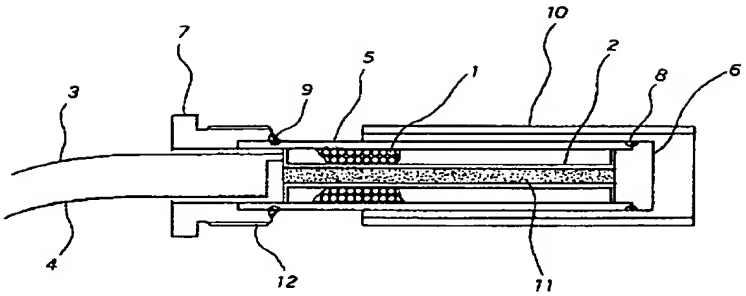
【符号の説明】

１	コイル
１０	外筒
１３	励振源
１４	加算器
１５	電圧・電流変換器
１６	低域フィルタ
１７	高域フィルタ
１８，１９	抵抗回路
４２	ディジタルポテンショメータ
４５	クワドラチュア発振器

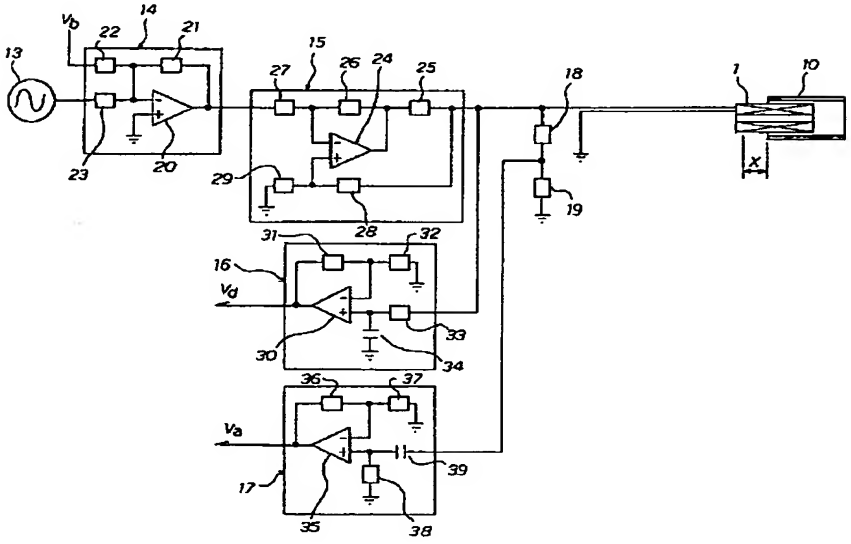
【図３】



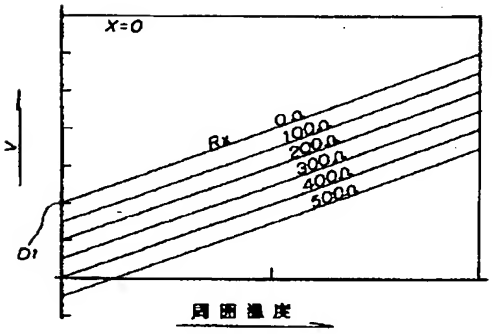
【図１】


10
7
5
1
2
8
6
3
9
4
12
11

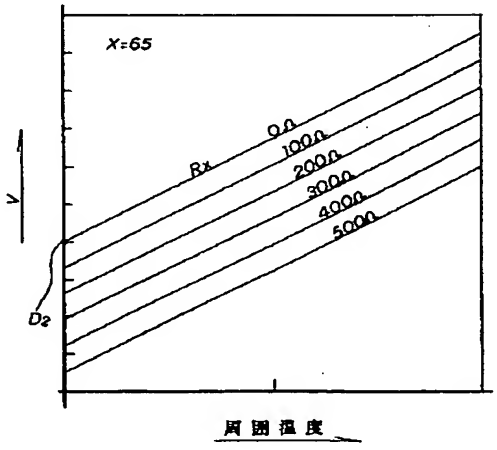
【図２】


Vb
14
22
21
13
15
27
26
24
25
18
1
10
23
20
29
28
19
X
31
32
16
Vd
33
30
34
36
37
Va
39
17
35
38

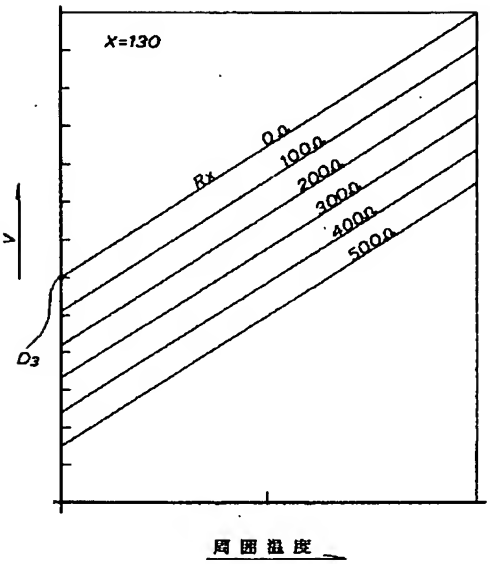
【図４】


X=0
V
Rx
0Ω
100Ω
200Ω
300Ω
400Ω
500Ω
D1
周囲温度

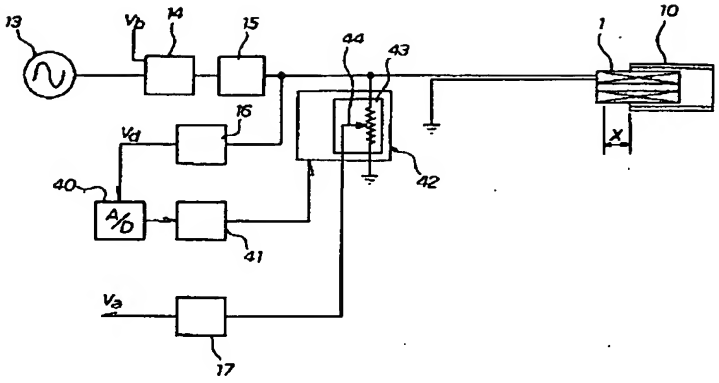
【図５】


X=65
V
Rx
0Ω
100Ω
200Ω
300Ω
400Ω
500Ω
D2
周囲温度

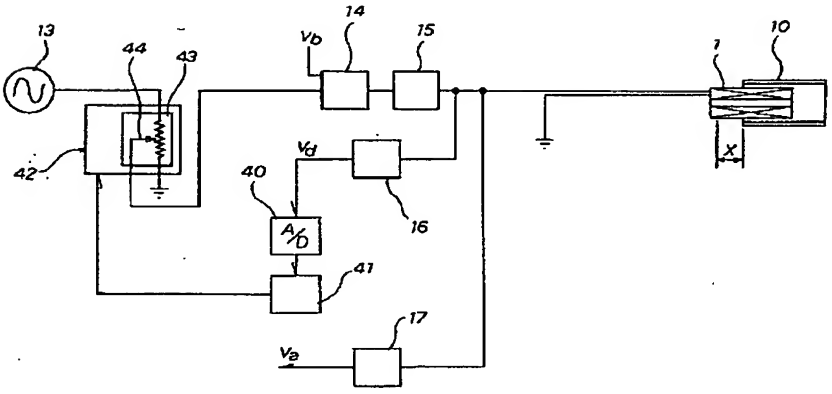
【図６】


X=130
Rx
0Ω
100Ω
200Ω
300Ω
400Ω
500Ω
V
D3
周囲温度

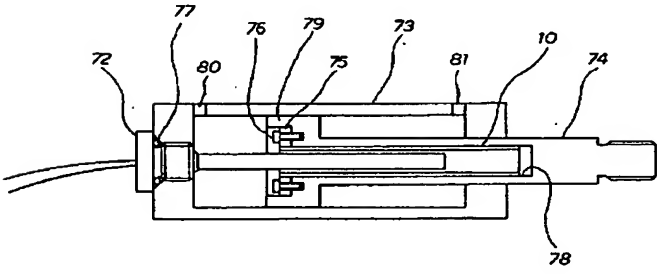
【図７】


13
Vb
14
15
44
43
1
10
16
Vd
40
A/D
41
42
X
Va
17

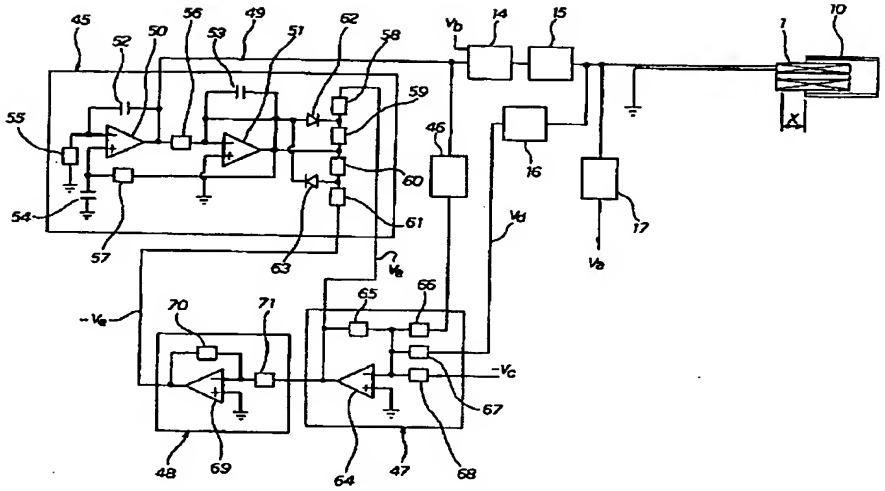
【図８】


13
44
43
Vb
14
15
1
10
42
Vd
40
16
A/D
41
17
Va
X

【図１０】


77
76
79
73
72
80
75
81
10
74
78

【図９】


45
52
50
56
53
49
51
62
58
Vb
14
15
1
10
59
55
46
60
16
54
61
17
57
63
Va
Vb
65
66
-Va
70
71
-Vc
67
48
69
64
47
68

DISPLACEMENT DETECTION APPARATUS

Patent Number: JP9033202
Publication date: 1997-02-07
Inventor(s): KYOIZUMI KOZO
Applicant(s): SANTESUTO KK
Requested Patent: JP9033202
Application Number: JP19950206834 19950721
Priority Number(s):
IPC Classification: G01B7/00; G01D5/20
EC Classification:
Equivalents:

Abstract

PROBLEM TO BE SOLVED: To provide a displacement detection apparatus in which one coil is used as a coil to detect a displacement, which can be miniaturized and in which a measured result is affected little by ambient temperature.
SOLUTION: A coil 1 which is wound to have a definite length and an outer tube 10 whose length is nearly equal to or longer than the length of the coil 1 and which is composed of a nonmagnetic and comparatively good electric conductor are arranged and installed so as to be movable in the axial-line direction of the coil 1. An AC current which has been biased by a DC current is supllied to the coil 1. A signal as an AC voltage which is changed proportionally to the relative displacement to the coil 1 of the outer tube 10 and which excludes a DC bias portion across terminals of the coil 1 or a signal which has converted the AC voltage into a DC voltage or a DC current is used as an output.

[Claim(s)]

[Claim 1] The outer case which consists of an electric good conductor comparatively by the coil wound around fixed die length, said coil, and nonmagnetic [which have an EQC or the die length beyond it mostly] is arranged in the direction of an axis of said coil movable. The alternating-voltage signal except a part for the direct-current deflection between the terminals of said coil which supplies the alternating current deflected by said coil by the direct current, and changes to the relative displacement over said coil of said outer case-like proportionally, Or displacement detection equipment characterized by considering as an output the signal which exchanged said alternating voltage for direct current voltage or a direct current.

[Claim 2] Displacement detection equipment which 2 sets of resistance circuits are connected to a serial between the terminals of said coil, and one [at least] resistance of said resistance circuit is proportionally changed to the direct current voltage generated among said end-winding children-like in displacement detection equipment according to claim 1, and is characterized by to acquire an output signal based on the electrical-potential-difference change except a part for the direct-current deflection obtained by the junction of said resistance circuit.

[Claim 3] Displacement detection equipment which a potentiometer is connected between the terminals of said coil, and the division ratio of said potentiometer is changed in displacement detection equipment according to claim 1 according to the direct current voltage generated among said end-winding children, and is characterized by acquiring an output signal based on the electrical-potential-difference change except a part for the direct-current deflection of the wiper electrical potential difference of said potentiometer.

[Claim 4] Displacement detection equipment which is changed according to the direct current voltage which generates the amplitude of the alternating current except a part for the direct-current deflection supplied to said coil among said end-winding children in displacement detection equipment according to claim 1, and is characterized by acquiring an output signal based on the electrical-potential-difference change except a part for the direct-current deflection between said end-winding children.

[Claim 5] In displacement detection equipment according to claim 1, a mulberry DORACHUA oscillator is used as a source of excitation of the alternating current except a part for the direct-current deflection supplied to said coil. Displacement detection equipment which is changed according to the direct current voltage which generates the electrical potential difference supplied to the circuit which consists of the resistance and diode which restrict the amplitude of the output of this oscillator among said end-winding children, and is characterized by acquiring an output signal based on the electrical-potential-difference change except a part for the direct-current deflection between said end-winding children.

[Claim 6] In displacement detection equipment according to claim 1, a mulberry DORACHUA

oscillator is used as a source of excitation of the alternating current except a part for the direct-current deflection supplied to said coil. While changing the electrical potential difference supplied to the circuit which consists of the resistance and diode which restrict the amplitude of the output of this oscillator based on the difference of the direct current voltage and reference voltage proportional to the amplitude or actual value of an ac output of said mulberry DORACHUA oscillator Displacement detection equipment which is changed also with the direct current voltage generated among said end-winding children, and is characterized by acquiring an output signal based on the electrical-potential-difference change except a part for the direct-current deflection between said end-winding children.

[Detailed Description of the Invention]

[0001]

[Industrial Application] the industrial machinery of this invention is mechanical -- level change of a variation rate or a liquid is depended on a float etc. -- mechanical -- the variation rate which changes into a variation rate and outputs the change as an electrical signal -- it is related with detection equipment.

[0002]

[Description of the Prior Art] Various methods are proposed from the former as equipment which detects a variation rate. A differential transformer or a potentiometer can be mentioned as most classic thing. Although a differential transformer can detect a variation rate by no contacting fundamentally, while there is a fault to which the displacement detection direction die length of detection equipment becomes large to an effective displacement detection measuring range, there is a fault which the moving part (core of a differential transformer) of detection equipment tends to damage by mechanical oscillation and the impact on the principle structure. although the potentiometer is used for many machineries since it is cheap -- theoretic -- a contact process -- a variation rate -- it is detection equipment and there is a problem that a limitation is in a life.

[0003] As an example which improved the above-mentioned conventional method (especially differential transformer), JP,63-273001,A, JP,63-273002,A, JP,2-116712,A, JP,2-201114,A, JP,3-46512,A, etc. can be mentioned, maintaining the description which did not contact. The core with which each of these examples is prepared in the core of a coil is fixed, a metal outer case is arranged in the direction of an axis of a coil at the periphery section of this coil so that it may be movable, and the relative displacement over the coil of a metal outer case is changed into an electrical signal.

[0004] This example of amelioration can embody the displacement detection equipment which has strong structure mechanically as indicated by the above-mentioned open patent official report.

[0005] However, in displacement detection equipment, what has a few change of an output signal is required from the temperature change of the strength of the mechanical structure, its engine performance, especially a perimeter.

[0006] In JP,63-273001,A, in order to improve the temperature characteristic, two of Coils A and B are prepared in shaft orientations. Since a coil becomes two pieces for it to be this method, the shaft-orientations die length of equipment becomes large. In order to improve this fault, the method which installs two coils is proposed in JP,63-273002,A.

[0007] In JP,2-116712,A, one side of two coils is installed in somewhere else, and the miniaturization of displacement detection equipment is in drawing. JP,2-201114,A and JP,3-46512,A also propose a miniaturization in the same idea.

[0008] Anyway, two coils tend to be connected to a differential mold and it is going to improve the temperature characteristic of displacement detection equipment. However, only the very big temperature characteristic in practice in degree C and 300-900 ppm /is acquired also by this method. Even if it makes it a differential mold using two coils, since this reason has the inductance from which two coils differ, corresponding to a variation rate with a natural thing, it is because perfect temperature compensation is not made.

[0009]

[Objects of the Invention] Then, this invention drives a coil by the alternating current by which bias was carried out by the dc component, and proposes the displacement detection equipment in which direct-current-voltage change produced by this dc component applied changing-like proportionally, and the temperature-compensation property was excellent with ambient temperature while it makes the coil for detecting a variation rate one piece and attains the miniaturization of equipment.

[0010]

[Means for Solving the Problem] This invention arranges the outer case which consists of an electric good conductor comparatively by the coil wound around fixed die length, said coil, and nonmagnetic [which have an EQC or the die length beyond it mostly] movable in the direction of an axis of said coil. The alternating-voltage signal except a part for the direct-current deflection between the terminals of said coil which supplies the alternating current deflected by said coil by the direct current, and changes to the relative displacement over said coil of said outer case-like proportionally, Or said technical problem was solved with the displacement detection equipment characterized by considering as an output the signal which exchanged said alternating voltage for direct current voltage or a direct current.

[0011] In addition, as a suitable embodiment of this invention, 2 sets of resistance circuits are connected to a serial between the terminals of ** coil. It is made to change to the direct current voltage which generates one [at least] resistance of this resistance circuit among end-winding

children-like proportionally. The displacement detection equipment which acquires an output signal based on the electrical-potential-difference change except a part for the direct-current deflection obtained by the junction of this resistance circuit, ** Connect a potentiometer between the terminals of a coil and change the division ratio of this potentiometer according to the direct current voltage generated among end-winding children. The displacement detection equipment which acquires an output signal based on the electrical-potential-difference change except a part for the direct-current deflection of the wiper electrical potential difference of this potentiometer, ** Make it change according to the direct current voltage which generates the amplitude of the alternating current except a part for the direct-current deflection supplied to a coil among end-winding children. The displacement detection equipment which acquires an output signal based on the electrical-potential-difference change except a part for the direct-current deflection between this end-winding child, ** Use a mulberry DORACHUA oscillator as a source of excitation of the alternating current except a part for the direct-current deflection supplied to a coil. It is made to change according to the direct current voltage which generates the electrical potential difference supplied to the circuit which consists of the resistance and diode which restrict the amplitude of the output of this oscillator among end-winding children. The displacement detection equipment which acquires an output signal based on the electrical-potential-difference change except a part for the direct-current deflection between this end-winding child, And a mulberry DORACHUA oscillator is used as a source of excitation of the alternating current except a part for the direct-current deflection supplied to ** coil. While changing the electrical potential difference supplied to the circuit which consists of the resistance and diode which restrict the amplitude of the output of this oscillator based on the difference of the direct current voltage and reference voltage proportional to the amplitude or actual value of an ac output of this mulberry DORACHUA oscillator It is made to change also with the direct current voltage generated among end-winding children, and there is displacement detection equipment which acquires an output signal based on the electrical-potential-difference change except a part for the direct-current deflection between this end-winding child.

[0012]

[Function] There is one coil driven with an AC signal in this invention. The alternating-voltage signal except a part for the direct-current deflection between the terminals of said coil which supplies the alternating current deflected by said coil by the direct current, and changes to the relative displacement over said coil of said outer case-like proportionally, Or since it can take out as a signal which exchanged said alternating voltage for direct current voltage or a direct current, while the miniaturization of this seed displacement detection equipment is realizable, it becomes possible to aim at improvement in a temperature-compensation property.

[0013]

[Example] Drawing 1 shows an example of the displacement detection equipment of the example of this invention. The coil 1 is wound around the bobbin 2 in drawing 1 . In this example, although the coil 1 is wound around two-layer, the number of them one, and the multilayer volume exceeding two-layer is sufficient as it. A coil 1 is what was prepared in displacement detection shaft orientations only one piece, and is connected to the electrical circuit where the leaders 3 and 4 of this coil are shown in drawing 2 , drawing 7 , drawing 8 , and drawing 9 . A metallic pipe 5 consists of a metallic pipe of an electric bad conductor, for example, austenite stainless steel SUS304 grade, comparatively by nonmagnetic, and the ends of this metallic pipe 5 have sealing structure closed with the head plug 6 and the head plug 7. Although it is closing by welding in this example as signs 8 and 9 show, the means of attachment which gave seal nature with the O ring etc. may be used. It says from the principle of operation of this invention, and the same construction material as a metallic pipe 5 of the head plug 6 and the head plug 7 is also desirable. Moreover, when seldom requiring a mechanical strength, 5, 6, and 7 may consist of construction material of a plastic or the ceramics.

[0014] An outer case 10 is comparatively manufactured by nonmagnetic from an electric good conductor, for example, copper, a copper alloy, aluminum, or an aluminum alloy. The relative displacement of this outer case 10 is carried out to a coil 1 in the direction of an axis of a coil 1, and the inductance of a coil 1 changes [an outer case 10] the role of a kind of short coil according to the variation rate of nothing and an outer case 10 to a coil 1. Although a core 11 is inserted in the core of a bobbin 2 and its construction material with sufficient permeability, for example, a permalloy etc., is desirable, a core 11 may not be indispensable and a cavity is sufficient as the core of a bobbin 2. However, in the case of a cavity, it must be ready for the rate of change (sensibility) over the variation rate of the outer case 10 of the inductance of a coil 1 becoming small.

[0015] In addition, the sign 12 of drawing 1 is the thread part prepared in the head plug 7, and it enables it to thrust it into a device, as shown in application drawing 10 mentioned later.

[0016] Next, drawing 2 shows the electrical circuit and signal detector which drive the coil 1 which is the main part of the displacement pickup of this invention. The circuit of drawing 2 consists of the source 13 of excitation, an adder 14, the voltage-current converter 15, a low-pass filter 16, a high-pass filter 17, a resistance element 18, and a resistance element 19. One side of the leaders 3 and 4 of a coil 1 is connected to the output of the voltage-current converter 15, and other leaders are connected to the gland of the circuit of drawing 2 .

[0017] the AC signal which sways focusing on Ov as shows the source 13 of excitation in the left figure of drawing 3 -- a sine wave-like AC signal is outputted desirably. An adder 14 consists of an operational amplifier 20 and resistance 21, 22, and 23, and the output of this adder 14 serves as an AC signal with which only Vb as shown in the right figure of drawing 3

was deflected from Ov. The output of this adder 14 will be impressed to the voltage-current converter 15 of the next step, and the current proportional to this impressed electrical potential difference will flow in a coil 1. That is, the alternating current deflected from the current value 0 as shown in the right figure of drawing 3 will flow in a coil 1. However, the right figure of drawing 3 shows the output of an adder 14.

[0018] In addition, the voltage-current converter 15 showed one of an operational amplifier 24 and the typical conventional examples which consist of resistance 25, 26, 27, 28, and 29. As long as it is the circuit which can supply the current proportional to the output voltage of an adder 14 to a coil 1, what kind of thing may be used. Since the inductance of a coil 1 changes to the relative displacement over the coil 1 of an outer case 10-like proportionally as already stated, between two leaders 3 and 4 of this coil 1, the alternating-voltage signal which changes to the relative displacement over the coil 1 of an outer case 10-like proportionally will be acquired. The alternating voltage which described the inductance of a coil 1 above since the outer case 10 became large proportionally by drawing 2 moving rightward (direction where X becomes large) also becomes large-like proportionally.

[0019] The partial pressure of the electrical potential difference between two leaders 3 and 4 of a coil 1 is carried out by the resistance element 18 and the resistance element 19, and this electrical potential difference by which the partial pressure was carried out is told to a high-pass filter 17. A high pass filter 17 is a typical circuit which consists of an operational amplifier 35, resistance 36, 37, and 38, and a capacitor 39. Direct-current deflection if the value of resistance 38 and a capacitor 39 is chosen suitably, as shown in the right figure of drawing 3 - Only the AC signal which sways focusing on Ov from which Vb was removed can be acquired as an output Va of a high-pass filter 17. If this Va has a fixed ambient temperature as already stated, it is proportional to the relative displacement over the coil 1 of an outer case 10.

[0020] Moreover, it is a direct-current deflection if the value of resistance 33 and a capacitor 34 is chosen suitably, as been the typical circuit where the electrical potential difference between two leaders 3 and 4 of a coil 1 is also told to a low-pass filter 16, and this low-pass filter 16 consists of an operational amplifier 30, resistance 31, 32, and 33, and a capacitor 34, and shown in the right figure of drawing 3 . - The direct current voltage Vd equivalent to Vb can be obtained.

[0021] Now, it is proportional to the direct-current-resistance value of a coil 1, and this direct-current-resistance value is proportional to the ambient temperature T of a coil 1, and that of the above-mentioned direct current voltage Vd is unrelated to the inductance of a coil 1. That is, Vd can be expressed with the following formula if alpha and beta are made into a constant.

Vd=alpha-T+beta The inductance of a coil 1 not only changes according to the variation rate of an outer case 10, but it changes it by change of the ambient temperature of a coil 1 so that

clearly also from the experimental result of which --** after-mentioned is done. The central description of this invention is in the place which proposes the displacement detection equipment which applied the relation shown by ** formula and was excellent in the temperature characteristic.

[0022]

[Example(s) of Experiment] In order to prove the effectiveness of this invention, the displacement detection equipment shown by drawing 1 was made as an experiment. The wire size of a coil 1 was 0.2=, 150= and the outer diameter of a bobbin 2, i.e., the bore of a coil 1, made shaft-orientations die length 4=, and two-layer winding was carried out. The effective successive range of an outer case 10 was made into 130= less than 10= from the ends of shaft-orientations die-length 150= of a coil 1.

[0023] Drawing 4 , drawing 5 , and drawing 6 show an example of an experimental result, drawing 4 shows X=0= and, as for drawing 5 , X=65= and drawing 6 show the case of X=130=. The axis of abscissa in drawing is ambient temperature, and an axis of ordinate shows the electrical potential difference of the output Va of a high-pass filter 17. In the experiment, the resistance element 19 was set to fixed-resistance 20Kohm, and the resistance element 18 was changed from 0ohm every 100ohms. That is, the experimental result described as 0 ohm in drawing 4 - drawing 5 shows the case where there is no partial pressure effectiveness by resistance elements 18 and 19.

[0024] It turns out the magnitude of the inductance of a coil 1, and that in other words rate of change [as opposed to the ambient temperature of an output signal by the difference in the location of an outer case 10] differs greatly so that clearly from these experimental results. For example, when a resistance element 18 is 0ohm and the temperature characteristic is calculated by considering effective-measuring-range 130= of displacement detection equipment as a full stroke (FS), it is at the time of X=0=. At the time of 485 ppmFS/degree-CX=65= At the time of 1004 ppmFS/degree-CX=130= It was 1524 ppmFS/degree C. (Notes: Change of Va when an outer case 10 does 130= displacement of under certain conditions the ambient temperature of 20 degrees C was 3783mvAC(s).) Rate of change per [to these 3783mvAC(s)] degree C It is each above-mentioned numeric value which was expressed with ppm.

[0025] Thus, it is the reason which cannot finish carrying out temperature compensation thoroughly even if that the temperature characteristic changes with variation rates makes it the differential method which used two coils by the advanced technology mentioned above.

[0026] Now, it turned out that data can be approximated by the linear equation shown below from the experimental result of drawing 4 - drawing 5 .

At the time of X=0= Va=1.833 and T+D1- (7/100), Rx -- At the time of ** X=65= Va=3.800 and T+D2- (15/100), Rx -- At the time of ** X=130= Va=5.8767 and T+D3- (23/100), Rx --**,

however Va: Output T of a high-pass filter 17 : Ambient temperature Rx: Value of the output signal Va at the time of the resistance D1 and D2 of a resistance element 18 and D3:T=0, and Rx=0 [0027] Here, supposing Rx may change the resistance to linearity to ambient temperature, it is Rx=kappa 1T. + kappa 2 -- If it becomes a constant and this is substituted for equation ** at the time of X=65=, **, however kappa1 and kappa2 will be Va=[3.800- (15/100) and kappa 1] and T+D2-15kappa2/100. -- It becomes ** .

[0028] ** If the multiplier of ambient temperature T is 0 in a formula, the output signal Va of a high-pass filter 17 at least will not be influenced at all by ambient temperature at the time of X=65=. Then, when the value of kappa 1 in this case is calculated, it is 3.800-15/100 and kappa1=0kappa1=25.333. -- When kappa 1 obtained by **** formula is substituted for equation ** and ** of a case of X=0= and X=130=, the multiplier of each T is at the time of X=0=. At the time of 0.06X=130= It is set to -0.06. Since the maximum variates of the output voltage Va in the effective successive range (under an ambient-temperature [of 20 degrees C] fixed condition) of the outer case 10 in this prototype were 3783mvAC(s), if this is considered as a full stroke and the temperature characteristic is calculated At the time of X=0= 0.06 / 3783= 15.8 ppmFS/degree C At the time of X=130= It turned out that it becomes -0.06 / 3783= 15.8 ppmFS/degree C, and the temperature characteristic which was dramatically excellent in the effective successive range whole region of displacement detection equipment can be acquired.

[0029] As already stated, it was shown that the output Vd of a low-pass filter 16 is proportional to the surrounding temperature T by ** formula. Therefore, if the resistance of a resistance element 18 can be proportionally changed-like to Vd, the effectiveness by this invention can be acquired. Although a detail is not illustrated in drawing 2 , the effectiveness described above when the resistance element 18 was used as the FET transistor and the gate voltage was controlled by the output Vd of a low-pass filter 16 for example, will be acquired.

[0030] Drawing 7 shows a more concrete example of the example of this invention. In addition, the same number was attached to what has the same function as the component part of the circuit shown by drawing 2 .

[0031] It is the example which replaced with the resistance element 18 and resistance element 19 in drawing 2 , and used the digital potentiometer 42 (semiconductor integrated circuit ADby Analog Devices, Inc. 8402 grade can specifically be used.). This digital potentiometer 42 can set the location of the wiper 44 of a potentiometer 43 as arbitration with the digital signal of an arithmetic circuit 41. That is, the electrical potential difference obtained by the wiper 44 of a potentiometer 43 is equivalent to the electrical potential difference in which the partial pressure was carried out by the resistance element 18 and resistance element 19 in drawing 2 .

[0032] It is good to change the output signal Vd of a low-pass filter 16 into a digital signal with A/D converter 40, to acquire the digital signal which should control the digital potentiometer 42

by the arithmetic circuit 41 which consists of microprocessors etc. here, and to decide the location of the wiper 44 of a potentiometer 43 according to ambient temperature. It is as follows when this point is explained a little in more detail. That is, when a resistance element 19 was made into the fixed resistance of 20Kohm in drawing 2 , kappa1=25.333 were the optimal so that it might see at a ** ceremony. This shows that what is necessary is just to reduce 25.333ohms of Rx(es) at a time whenever 1 degree C of surrounding temperature changes so that more clearly than ** type. If this is expressed as a division ratio of a resistance element 18 and a resistance element 19 (cube of 20-10) / (cube +25.333andT of 20-10) -- It becomes **.

[0033] Therefore, in the circuit of drawing 7 , it is good to decide with the division ratio of a potentiometer 43, and the relation which in other words shows the location of the wiper 44 of a potentiometer 43 by ** formula. As already stated, it can ask for ambient temperature T easily from ** type.

[0034] Drawing 8 shows other examples of this invention. Also in drawing 8 , the same number was attached to what has the same function as the component part of the circuit shown by drawing 2 or drawing 7 . Although the potentiometer 43 is formed between the leaders of a coil 1 in drawing 7 , the signal of the wiper 44 of a potentiometer 43 is impressed to an adder 14 in drawing 8 . Moreover, the signal of a coil 1 which changes according to the variation rate of an outer case 10 is told to the direct high-pass filter 17, and an output signal Va is taken out.

[0035] As change of the ambient temperature of a coil 1 was already described, it is detected as an output signal Vd of a low-pass filter 16, and this output signal Vd is changed into a digital signal by A/D converter 40, the digital signal which should control the digital potentiometer 42 by the arithmetic circuit 41 is acquired, and the location of the wiper 44 of a potentiometer 43 is decided according to ambient temperature. That is, if ambient temperature changes, the AC signal with which the amplitude of the AC signal of the source 13 of excitation changed according to it, and this amplitude changed is added to an adder 14, and, eventually, it is going to acquire the displacement signal Va which does not induce change of ambient temperature.

[0036] It is as follows when this point is explained using a formula. Fluctuation part **Va by the ambient temperature T of the output signal Va of displacement detection equipment is expressed with ** type so that clearly also from the graph at the time of Rx=0ohm of drawing 4 , drawing 5 , and drawing 6 .

Va=(alpha1 and X+beta 1) -T -- beta 1 of ** type is the sensitivity to the temperature T at the time of X= 0, and alpha1 and X show that this sensitivity becomes large according to the magnitude of X. It is the multiplier it is uniquely decided by the specification of a coil 1 that alpha1 and beta1 will be.

[0037] Moreover, ambient temperature T can be detected as an output Vd of a low-pass filter 16, and shows the fluctuation part **Vd like (10) types so that clearly [** type].

**Vd=alpha2andT -- The output signal Vd of (10), now displacement detection equipment changes also with the magnitude of the AC signal added to a coil 1. Fluctuation part **Va of the output signal Va by this control since the circuit of drawing 8 is constituted so that the magnitude of the AC signal which the source 13 of excitation outputs can be controlled by Vd is **Va= (alpha3 and X+beta 3) and **Vd. -- It is set to (11). (11) The formula shows that the rate of change of Va [as opposed to Vd with a natural thing] is dependent on the magnitude of X, i.e., the magnitude of the inductance of a coil 1.

[0038] The following (12) types are obtained from (10) and (11) types.

**Va=(alpha3 and X+beta 3) -alpha2andT -- (12)

(9) If the difference of a formula and (12) types is taken (alpha1 and X+beta 1) -T-(alpha3 and X+beta 3) -alpha2 and T = [(alpha1-alpha3, alpha 2) -X- (beta1-beta3, alpha 2)] -T -- (13)

It becomes.

[0039] (13) It is alpha1-alpha3 and alpha2=0 so that clearly from a formula. -- (14)

beta1-beta3 and alpha2=0 -- (15)

If it ******, it will not be influenced at all by ambient temperature T.

[0040] A concrete numeric value is applied to (14) and (15) types. it already stated -- as -- alpha1 and beta1 -- the specification of a coil 1 -- being decided -- a prototype -- a variation rate -- detection equipment -- alpha1=30.26x (10 - cubes) from (2), (3), and (4) types

beta1=1.833, and alpha3 and beta3 are alpha3=5.498x (10 - cubes).

It was beta3=0.333. Since alpha 2 can be chosen as arbitration, if it chooses out of (14) types with alpha2=alpha1/a3=5.504, (14) types will be satisfied first. Next, it is if beta1, beta3, and alpha2 which are the above are substituted for (15) types. beta1-beta3 and alpha2=1.833-0.333x5.504 It is set to **0 and (15) types are also satisfied.

[0041] In order to use the digital potentiometer 42 in order to change the amplitude of the AC signal of the source 13 of excitation, and to control this digital potentiometer 42 by the example of drawing 8 , an arithmetic circuit 41 and A/D converter 40 are needed, and circuitry becomes complicated a little. In view of this point, other examples are shown in the pan which constituted all the circuits from an analog circuit at drawing 9 .

[0042] In drawing 9 , the mulberry DORACHUA (Quadrature) oscillator circuit 45 was used as a thing equivalent to the source 13 of excitation of drawing 8 . The sine wave which vibrates another integrating circuit which consists of the integrating circuit which consists of an operational amplifier 50, a capacitor 52, and resistance 55, an operational amplifier 51, a capacitor 53, and resistance 56 focusing on 0V by nothing and self-excited vibration to a closed circuit by resistance 57 and the capacitor 53 at the output of an operational amplifier 50 is acquired.

[0043] The oscillation stabilized when setting capacitors 52, 53, and 54 to C equally, setting

resistance 55 and 56 to R equally and making resistance 57 slightly larger than R with extent 10% or less is obtained, and the oscillation frequency f serves as f=1/2piRC.

[0044] The amplitude of the sine wave on a leader 49 is proportional to the electrical potential difference Ve which is restricted by resistance 58, 59, 60, and 61 and diodes 62 and 63, and is supplied from the outside through resistance 58 and 61, and -Ve.

[0045] Now, a sign 46 is a full wave rectifier etc., it outputs direct current signals, such as actual value of a sine wave, or magnitude of the amplitude, and negative feedback is carried out to an adder subtracter 47. Adder subtracters 47 are an operational amplifier 64 and phase inversion amplifier which consists of resistance 65, 66, 67, and 68. Now, it is assumed that the output voltage Vd of the low-pass filter 16 proportional to the ambient temperature of a coil 1 is 0v. Fixed electrical potential difference which will be impressed from the outside through resistance 68 if the value of resistance 65 is enlarged in comparison rather than resistance 66 and 68 - An electrical potential difference Ve is controlled so that the output of a full wave rectifier 46 is in agreement with the absolute value of Vc. A sign 48 consists of resistance 70 and 71 which is typical inverters and has an operational amplifier 69 and the same resistance. - Ve is outputted and the mulberry DORACHUA oscillator circuit 45 is supplied through resistance 61. Namely, fixed electrical potential difference impressed from the outside according to the example shown by drawing 9 - It becomes possible to acquire the sine wave which sways focusing on 0v which has the amplitude proportional to the absolute value of Vc to a leader 49.

[0046] Now, the case where the ambient temperature of a coil 1 next changes is considered. As already stated, this ambient temperature is detectable due to (1) type as output voltage Vd of a low-pass filter 16. Since Vd is impressed to this adder subtracter through the resistance 67 of the adder subtracter 47 in drawing 9 , the amplitude of the sine wave acquired by the leader 49 will change according to fluctuation of the ambient temperature of a coil 1. If the resistance of resistance 67 is suitably chosen to the resistance of resistance 66 and 67, (14) and (15) types which were already described can be satisfied.

[0047] In addition, the output signal Va proportional to the relative displacement over the coil 1 of an outer case 10 is good also considering the rectified direct current voltage which is good also as an output and can acquire the actual value easily with the conventional technique as an output signal. Or when Va is a sine wave, what held the peak value and was changed into direct current voltage may be used. Anyway, the electrical signal which suited the object proportional to the variation rate of an outer case 10 can be acquired easily. Moreover, you may make it not only a voltage signal but a current signal.

[0048]

[Example(s) of Application] Drawing 10 shows the example which detects the variation rate of the rod of a nest cylinder for the displacement detection equipment by this invention in an oil

pneumatics cylinder. The displacement detection equipment 72 of a configuration of that drawing 1 showed is thrust into the side pars basilaris ossis occipitalis of an oil hydraulic cylinder 73, and a seal is carried out with O ring 50. That is, drawing 10 shows the example which may be built in the cylinder to which an application-of-pressure fluid is added.

[0049] The outer case 10 of displacement detection equipment is inserted in the hole 78 established in the core of a rod 74, and the flange 75 which fixed at the edge of this outer case 10 is attached by the piston section 79 of a cylinder with the bolt 76. The fluid pressurized through the port 80 of a cylinder 73 or 81 by this structure is supplied to the interior of a cylinder 73, a rod 74 expands and contracts, and the displacement detection equipment 72 by this invention detects the variation rate of this telescopic motion. Thus, since it is the structure which can contain a coil 1 in the firm container sealed with the metallic pipe 5 in drawing 1 , the head plug 6, and the head plug 7, it becomes possible to use for an application like drawing 9 .

[0050] Although it is natural, it cannot be overemphasized that an application is not restricted to drawing 10 , but an outer case 10 is attached at least in the moving part of a common industrial machine, and a variation rate can be detected.

[0051]

[Effect of the Invention] Since the coil for detecting a variation rate was made into one piece according to the configuration of claim 1, this miniaturized kind of displacement detection equipment can be obtained. And with claim 2 thru/or the configuration of 6, the displacement detection equipment which was excellent in the temperature-compensation property can be obtained.

[Brief Description of the Drawings]

[Drawing 1] The axial sectional view of the example of the displacement detection equipment of this invention.

[Drawing 2] Drawing having shown the example of the outline and actuation circuit of the displacement detection equipment of drawing 1 , and a signal detector.

[Drawing 3] The AC signal output to which left-hand side sways focusing on Ov of the source of excitation, and right-hand side show the wave of the AC signal output of the adder with which only Vb was deflected from Ov, respectively.

[Drawing 4] It is the graph showing the experimental result which showed how output voltage would be influenced with ambient temperature, and is the case where a variation rate is zero.

[Drawing 5] It is the graph showing the experimental result which showed how output voltage would be influenced with ambient temperature, and is the case where a variation rate is medium.

[Drawing 6] It is the graph showing the experimental result which showed how output voltage would be influenced with ambient temperature, and is the case where a variation rate is max.

[Drawing 7] Drawing having shown another example of the outline and actuation circuit of the

displacement detection equipment of drawing 1 , and a signal detector.

[Drawing 8] Drawing having shown still more nearly another example of the outline and actuation circuit of the displacement detection equipment of drawing 1 , and a signal detector.

[Drawing 9] Drawing having shown still more nearly another example of the outline and actuation circuit of the displacement detection equipment of drawing 1 , and a signal detector.

[Drawing 10] The axial sectional view in the case of being included in an oil pneumatics cylinder and detecting the variation rate of the rod of a cylinder by the application of this invention.

[Description of Notations]

1 Coil

10 Outer Case

13 Source of Excitation

14 Adder

15 Voltage-current Converter

16 Low-pass Filter

17 High-pass Filter

18 19 Resistance circuit

42 Digital Potentiometer

45 Mulberry DORACHUA Oscillator